FIG. 5 graphically depicts the closed loop performance of the MVU estimator of the instant invention by comparing the frequency offset estimate of the closed loop MVU estimator and the analytical derivation given in equation (28). It is clear that the simulation result very closely resembles the analytical model, thus consolidates the approximate model of the closed loop system.

Numerous variations and modifications will become evident to those skilled in the art once the disclosure is fully appreciated. It is intended that the following claims be interpreted to embrace all such variations and modifications.

WHAT IS CLAIMED IS:

1. A method of estimating carrier frequency offset error in a received sample bit stream including an observation vector (OV), having an observed carrier frequency timing offset ε, and a plurality of data-symbol frames, having a symbol timing offset error ϑ, comprising the steps of:

generating a probability density function (PDF) based on said OV; and

generating from said PDF an estimate of carrier frequency offset error, $\varepsilon_{MVU|\vartheta}$, being a minimum variance unbiased (MVU) estimator.

2. The MVU carrier frequency offset error estimation method of claim 1 wherein said OV comprises an L-bit cyclic extension portion and a first and a second N-bit synchronization frame, and wherein said PDF comprises a first term, p1, based on said timing offset ϑ being within the span 1 to N and a second term, p2, based on said timing offset ϑ being within the span N+1 to N+L.

3. The MVU carrier frequency offset error estimation method of claim 2 wherein said received bit stream has uncorrelated independent identically distributed random signal and noise sequence variables with power of σ_s^2 and σ_n^2, respectively, wherein said OV is denoted **x**, and wherein said MVU estimator $\varepsilon_{MVU|\vartheta}$ is the conditional expectation of a second moment estimator, said second moment estimator given by

$$\breve{\varepsilon} = \frac{\Im}{2\pi} \ln\left\{ \frac{1}{L\sigma_s^2} \sum_{k=\vartheta}^{\vartheta+L-1} x[k]x^*[k+N] \right\}.$$

4. The MVU carrier frequency offset error estimation method of claim 3 wherein said MVU estimator $\varepsilon_{MVU|\vartheta}$ is given by

$$\breve{\varepsilon}_{MVU|\vartheta} = E\left(\breve{\varepsilon} \middle| _{T_1(\mathrm{x},\vartheta)}\right) = \frac{\Im}{2\pi} \ln E\left\{ \frac{1}{L\sigma_s^2} \sum_{k=\vartheta}^{\vartheta+L-1} x[k]x^*[k+N] \middle| _{T_1(\mathrm{x},\vartheta)} \right\}$$

$$= \frac{1}{2\pi} \Im\left\{ \ln \frac{T_1(\mathrm{x},\vartheta)}{L\sigma_s^2} \right\}$$

where $\Im$ is the imaginary operator and where

$$T_1(\mathrm{x},\vartheta) = \begin{cases} \sum_{k=\vartheta}^{L+\vartheta-1} x[k]x^*[k+N] & 1 \le \vartheta \le N \\ \sum_{k=0}^{\vartheta-N-1} x[k]x^*[k+N] + \sum_{k=\vartheta}^{N+L-1} x[k]x^*[k+N] & N+1 \le \vartheta \le N+L \end{cases}.$$

5. A method of synchronizing a received sample bit stream, comprising the steps of:

transmitting at a transmitter said bit stream including an observation vector (OV);

receiving and sampling at a receiver said bit stream, said sampled bit stream including, said OV with an observed carrier frequency offset ε, and a plurality of data-symbol frames, having a symbol timing offset error ϑ ;

generating a probability density function (PDF) based on said OV;

generating from said PDF an estimate of carrier frequency offset error, $\varepsilon_{MVU|\vartheta}$, being a minimum variance unbiased (MVU) estimator; and

synchronizing said received bit stream by said MVU estimate of carrier frequency offset.

6. The synchronization method of claim 5 wherein said OV comprises an L-bit cyclic extension portion and a first and a second N-bit synchronization frame, and wherein said PDF comprises a first term, p1, based on said observed timing offset ϑ being within the span 1 to N and a second term, p2, based on said observed timing offset ϑ being within the span N+1 to N+L.

7. The synchronization method of claim 6 wherein said received bit stream has uncorrelated independent identically distributed random signal and noise sequence variables with power of σ_s^2 and σ_n^2, respectively, wherein said OV is denoted x, and wherein said MVU estimator $\varepsilon_{MVU|\vartheta}$ is the conditional expectation of a second moment estimator, said second moment estimator given by

$$\breve{\varepsilon} = \frac{\Im}{2\pi}\ln\left\{\frac{1}{L\sigma_S^2}\sum_{k=\vartheta}^{\vartheta+L-1} x[k]x^*[k+N]\right\}.$$

8. The synchronization method of claim 7 wherein said MVU estimator $\varepsilon_{MVU|\vartheta}$ is given by

$$\breve{\varepsilon}_{MVU|\vartheta} = E\left(\breve{\varepsilon}\Big|_{T_1(x,\vartheta)}\right) = \frac{\Im}{2\pi}\ln E\left\{\frac{1}{L\sigma_s^2}\sum_{k=\vartheta}^{\vartheta+L-1} x[k]x^*[k+N]\Big|_{T_1(x,\vartheta)}\right\}$$

$$= \frac{1}{2\pi}\Im\left\{\ln\frac{T_1(x,\vartheta)}{L\sigma_s^2}\right\}$$

where $\Im$ is the imaginary operator and

$$\text{where } T_1(x,\vartheta) = \begin{cases} \sum_{k=\vartheta}^{L+\vartheta-1} x[k]x^*[k+N] & 1 \le \vartheta \le N \\ \sum_{k=0}^{\vartheta-N-1} x[k]x^*[k+N] + \sum_{k=\vartheta}^{N+L-1} x[k]x^*[k+N] & N+1 \le \vartheta \le N+L \end{cases}.$$

9. A method of estimating carrier frequency offset error in a received sample bit stream including an observation vector (OV), having an observed carrier frequency timing offset ε, and a plurality of data-symbol frames, said OV comprising an L-bit cyclic extension portion and a first and a second N-bit synchronization frame, comprising the steps of:

generating the expected value of the autocorrelation of the *k*th entry of said OV; and

generating from said expected value an estimate of carrier frequency offset error, ε_{mom}, being a moment estimator.

10. The moment carrier frequency offset error estimation method of claim 9 wherein said OV is denoted **x**, and wherein said moment estimator ε_{mom} is given by

$$\hat{\varepsilon}_{mom} = \frac{\Im}{2\pi}\{\ln T_3(x)$$

where the statistic $T_3(x)$ is defined as

$$T_3(x) = \frac{1}{L\sigma_s^2} \sum_{k=0}^{N+L+1} x[k]x^*[k+N].$$

11. A method of synchronizing a received sample bit stream, comprising the steps of:

transmitting at a transmitter said bit stream including an observation vector (OV);

receiving and sampling at a receiver said bit stream, said sampled bit stream including, said OV with an observed carrier frequency offset ε, and a plurality of data-symbol frames, having a symbol timing offset error ϑ ;

generating the expected value of the autocorrelation of the *k*th entry of said OV;

generating from said expected value an estimate of carrier frequency offset error, ε_{mom}, being a moment estimator; and

synchronizing said received bit stream by said moment estimate of carrier frequency offset.

12. The synchronization method of claim 11 wherein said OV is denoted **x**, and wherein said moment estimator ε_{mom} is given by

$$\hat{\varepsilon}_{mom} = \frac{\Im}{2\pi}\{\ln T_3(x)$$

where the statistic $T_3(x)$ is defined as

$$T_3(x) = \frac{1}{L\sigma_S^2} \sum_{k=0}^{N+L+1} x[k]x^*[k+N].$$

13. A method of estimating carrier frequency offset error in a received sample bit stream including an observation vector (OV), having an observed carrier frequency timing offset ε, and a plurality of data-symbol frames, said OV comprising an L-bit cyclic extension portion and a first and a second N-bit synchronization frame, comprising the steps of:

selecting one estimator method from a group of three: a maximum likelihood (ML) estimator, a minimum variance unbiased (MVU) estimator, a moment estimator, based on said OV; and

generating from said selected estimator an estimate of carrier frequency offset error.

14. The carrier frequency offset error estimation method of claim 13 wherein said MVU estimator method comprises the steps:

generating a probability density function (PDF) based on said OV; and

generating from said PDF an estimate of carrier frequency offset error, $\varepsilon_{MVU|\vartheta}$, being said MVU estimator.

15. The carrier frequency offset error estimation method of claim 14 wherein said OV comprises an L-bit cyclic extension portion and a first and a second N-bit

synchronization frame, and wherein said PDF comprises a first term, p1, based on said timing offset ϑ being within the span 1 to N and a second term, p2, based on said timing offset ϑ being within the span N+1 to N+L.

16. The carrier frequency offset error estimation method of claim 15 wherein said received bit stream has uncorrelated independent identically distributed random signal and noise sequence variables with power of σ_s^2 and σ_n^2, respectively, wherein said OV is denoted x, and wherein said MVU estimator $\varepsilon_{MVU|\vartheta}$ is the conditional expectation of a second moment estimator, said second moment estimator given by

$$\breve{\varepsilon} = \frac{\Im}{2\pi}\ln\left\{\frac{1}{L\sigma_S^2}\sum_{k=\vartheta}^{\vartheta+L-1} x[k]x^*[k+N]\right\}.$$

17. The carrier frequency offset error estimation method of claim 16 wherein said MVU estimator $\varepsilon_{MVU|\vartheta}$ is given by

$$\breve{\varepsilon}_{MVU|\vartheta} = E\left(\breve{\varepsilon}\,\middle|_{T_1(x,\vartheta)}\right) = \frac{\Im}{2\pi}\ln E\left\{\frac{1}{L\sigma_s^2}\sum_{k=\vartheta}^{\vartheta+L-1} x[k]x^*[k+N]\middle|_{T_1(x,\vartheta)}\right\}$$

$$= \frac{1}{2\pi}\Im\left\{\ln\frac{T_1(x,\vartheta)}{L\sigma_s^2}\right\}$$

where $\Im$ is the imaginary operator and where

$$T_1(x,\vartheta) = \begin{cases} \sum_{k=\vartheta}^{L+\vartheta-1} x[k]x^*[k+N] & 1 \le \vartheta \le N \\ \sum_{k=0}^{\vartheta-N-1} x[k]x^*[k+N] + \sum_{k=\vartheta}^{N+L-1} x[k]x^*[k+N] & N+1 \le \vartheta \le N+L \end{cases}.$$

18. The carrier frequency offset estimation method of claim 13 wherein said moment estimator method comprises the steps:

generating the expected value of the autocorrelation of the *k*th entry of said OV; and

generating from said expected value an estimate of carrier frequency offset error, ε_{mom}, being said moment estimator.

19. The carrier frequency offset error estimation method of claim 18 wherein said OV is denoted **x**, and wherein said moment estimator ε_{mom} is given by

$$\hat{\varepsilon}_{mom} = \frac{\Im}{2\pi}\{\ln T_3(x)$$

where the statistic $T_3(x)$ is defined as

$$T_3(x) = \frac{1}{L\sigma_s^2}\sum_{k=0}^{N+L+1} x[k]x^*[k+N].$$